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The purpose of this study was to determine the effects of breath holding with calisthenics upon energy cost, resting heart rate, exercise heart rate, and recovery heart rate.

Twelve physical education graduate students at the University of North Carolina at Greensboro volunteered as subjects for the experiment, which consisted of a six weeks training program using breath holding with calisthenics as an exercise stimulus. Before the program began, the subjects were given a pre test, involving five minutes of rest, three minutes of stool stepping, and ten minutes of recovery. The caloric cost for the three minute exercise was determined by oxygen consumption. The subjects' heart rates were telemetered during participation in the stool stepping, and during the rest and recovery phases.

Eight calisthenics, performed three times a week by each participant, were used for the entire training program. At the end of the six week period, each subject was retested using the same procedure as was used for the pre test. Caloric cost, resting heart rate, exercise heart rate, and recovery heart rate differences were used to compare the results of the pre and post tests between the control and experimental groups.

Four null hypotheses were established at the beginning of the investigation. Each dealt with the four physiological parameters measured. Breath holding was found not to be an exercise stimulus for training when used during the performance of calisthenics.

AN INVESTIGATION OF BREATH HOLDING WITH EXERCISE CALISTHENICS

by

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CHAPTER I

INTRODUCTION

Lengthy breath holding exercises have long been noted as uncomfortable physiological and psychological experiences. One of the first uses of breath holding takes place in childhood, when the child threatens his parents with breath holding to get their attention or to threaten them with the hopes of bargaining for something.

Cureton[4:277] writes that physical fitness and breath holding ability are closely related. He continues to say that to hold the breath for a long time indicates a good cardiovascular system. Breath holding ability has been used by insurance companies to predict good risks.[25:356] These companies would assume that if a person, whom they were going to insure, could hold their breath for a long period, their body and cardiovascular systems must be functioning correctly.[25]

Michael[47:218] in a study of underwater swimming was interested in breath holding used as a stimulus for exercise. He felt that there was a relationship between breath holding and exercise. After examining and comparing scores made on a physical fitness test of trained athletes and underwater swimmers, he concluded that their fitness levels were very similiar and that breath holding can be used as a stimulus for exercise. "....it is not unreasonable to suggest that combining muscular activity with breath holding would improve conditioning more effectively than when exercise alone is used".[47:220] Montoye[63:117-118] states in his dissertation that breath holding produces stress and stress".... in the proper amounts builds a better more efficient organism."[64:2]

Stress on the body, when breath holding is used, is very uncomfortable to subjects, but the psychological factor, which tends to be very important intervenes. Lux studied[44] the physiological factors which are related to breath holding, and concluded: "Breath holding is related to: physical condition, emotional strain, ability to withstand the accompaning discomfort, and will power."[44:61] Schneider [60:464] in his study also reached the conclusion that men who could not hold their breath for a long period of time were not willing to continue the stress. The dedication and motivation, which subjects must have in a breath holding study are of most importance. They must be able to withstand the discomfort and misery, which this variable provides.

Although breath holding can not be said to produce endurance, [38:720] it can possibly assist in the body's determination to build endurance.

Purpose of the Study

The purpose of this study was to investigate the changes in exercise heart rate and exercise energy cost resulting from a training program using breath holding as compared with a training program employing normal breathing techniques.

Definition of Terms

1. Energy cost-The amount of calories consumed and burned during an exercise.

2. Endurance- The amount of time in which an exercise or work can be continued.[39:419]

3. Training Program- A group of calisthenics, performed three times a week, designed to improve all parts of the body with specific emphasis on the cardio-vascular system.

4. Gas Exchange- Carbon dioxide and oxygen exchange made by the lungs (alveoli) and the blood. Also the exchange made by the blood and tissues.

5. Breath Holding- "A mechanism by which the respiratory system can be shut off from its external environment"[8:195]

6. Scholander Gas Analyzer- "Permits the determination of carbon dioxide, oxygen and nitrogen in 0.5 ml of gas samples with an accuracy of plus-minus 0.015 volume percent. It will handle directly samples containing from 0 to over 99 per cent absorbable gases"[8:72]

7. Breaking Point - That point at which the subjects can no longer hold their breath.

8. Douglas bags-Apparatus used to collect expired air.

9. PCO_2 - Partial pressure of carbon dioxide in alveoli.

10. PO_2- Partial pressure of oxygen in alveoli.

11. $PACO_2$- Partial pressure of carbon dioxide in alveoli or arteries.

12. PAO_2- Partial pressure of oxygen in alveoli or arteries.

Limitations-

1. The different physiological makeups of the subjects should be considered as a limitation as well as the endurance capacity of each girl.

2. The amount of air which was inspired by the individuals before the start of the breath hold was unpredictable because of the depth of the breath as well as the lung capacity of the individuals.

3. A breaking point of breath holding was not to be used in the exercise program because of the possible hazards.

4. The diets of the subjects were not controlled, but they were asked to cooperate in limiting their food intake before each training period.

CHAPTER II

STATEMENT OF PROBLEM

The problem which was investigated dealt with the physiological effects of breath holding when used as a stimulus during exercise in a training program. Other considerations were the effects of breath holding during exercise and the improvement of the subject's endurance level. To determine the changes in the subject's endurance, the energy cost of an exercise was determined by the use of the Scholander gas analyzer and the changes from a pre test and post test were calculated. The exercise used was the stool stepping test with the metronome as a rhythm device.

CHAPTER III

REVIEW OF LITERATURE

"Breath holding is a mechanism by which the respiratory system can be shut off from its external environment. It provides man with a natural means by which to forsake his normal gaseous surroundings..."[8:195] This statement issued by Mithoefer in his study of breath holding sums up in a few lines how breath holding may be interpreted. Cureton [4:283] goes further into the definition of breath holding when he classifies it as an ability of the lungs and blood to do without the availability of oxygen. With this shortage of oxygen, the human response ranges anywhere from slight pain to extreme agony.[8:195]

Breath holding has been used for many purposes since the year 1900. The first and probably one of the most important uses of breath holding in the past has been as a test of physical fitness.[53:356, 4:277] If an individual could hold his breath for a long period of time, he was classified as being physically fit as far as oxygen use is concerned.[4:283] With the onset of World War I, breath holding became important to aviators; for altitude and breath holding were tested together and correlated to find the best flyers.[53:356] Since the war, physical educators have taken up the study of breath holding in relationship to athletics.

Breath holding can have many effects on the body, when it is held for a considerably long time. Schneider made the following observations: "With breath holding there are in addition to dizziness and blurred vision, profuse sweating, suffusion of the blood vessels of the head, pressure in the head, and a great sense of effort."[61:464-465]

Fowler[35] describes some of the strains which breath holding will put on the body. He comments on the reasoning why the breaking point must occur.

> Increasing voluntary effort also is required to inhibit and actively oppose the chemically stimulated muscular contractions, and the afferent barrage from the various muscles is probably large in intensity and disorganized, in that the natural pattern of alternating contractions and relaxation is changed. This situation eventually becomes intolerable. 35:544

He also emphasizes the relief of the body which occurs when breath holding is terminated.

> The termination of voluntary breath holding is customarily followed by relief of respiratory distress as vigorous unobstructed breathing movements are resumed and normal alveolar gas tensions are regained. 35:539

Craig and Cummings[27] observed a gradual deflation of the chest position after a maximal inspiration, but just before the breaking point, the chest quickly and almost unnoticeably rose, as if to be grasping for air. The writers thought this to be due to the contraction or a twitch of the abdominal muscles, which lifted the chest.[27:32] "Implications of this is that a critical stimulus to breath is approached during the hold at a rate proportional to the oxygen uptake." [27:34] The chest position needs further investigation as to its actual contribution to the termination of breath holding.

To investigate the physiology of breath holding and respiration, the process of gas exchange in the lungs, blood, and tissues must be understood. Mathews[13] defines respiration as "....the movement of air in and out of the lung spaces". [13:226] DeVries[6] defines gas transport or exchange as the "diffusion of oxygen across two very thin membranes, the wall of the alveolus and the wall of the capillary." [6:128] Morehouse[16:156] describes the gas exchange as being completely dependent upon one process-that of diffusion. If this process is tampered with in any way, such as breath holding, then changes in the diffusion process will take place, which will cause changes in the respiration system. An accepted pressure of 100 mm Hg. is said to be the partial pressure of oxygen in the alveolar air.[16:158, 13:228] The blood that is pumped from the right side of the heart has an oxygen pressure of 40 mm Hg.[16:158] This provides a diffusion gradient of 60 mm Hg. On the other hand, carbon dioxide in the alveolar air has a pressure of around 40 mm of Hg.[16:158, 57:228] and in the blood the carbon dioxide has a pressure of about 5 or 6 mm more than the alveolar air.[16:158] This gas exchange is also dependent upon the volume of inspired air which is taken into the lungs and will affect the diffusion coefficient.[17:140] This rate of diffusion is most important when the breath is held; for the diffusion gradient is lowered because of the volume of air in the lungs being cut off from the outside atmospheric air. This would indicate that the volume of air inspired at the beginning of breath holding is all that is used while the breath holding process is continued. Also the lung volume will gradually shrink during breath holding.[50:706] The average volume of gas which can be inspired by a human is around 500 cc.[16:143] Thus the partial pressure and accumulation of carbon dioxide in the alveolar sacs is increased and the oxygen is decreased.[58:228]

Vigorous exercise will tend to cause all of the above to occur at a faster rate. The concentration of carbon dioxide will increase at a more rapid rate as well as the demand for oxygen. The ability of the respiratory system to meet this increased demand will be hampered because no atmospheric air will enter the lungs during calisthenics, which will produce stress on the cardiovascular system and the gaseous exchange of lungs and blood, and blood and tissues. McCurdy[14] states:

> Muscular exercise increases the output of carbon dioxide. The increased activity of the respiratory center may be due primarily to associated stimuli from the motor cortex to the respiratory center, and secondarily to the metabolites going to the respiratory center in the blood. 14:121

Montoye[53] comments in his study that the length of time the breath can be held will be shortened when moderate exercise is executed.[51:328]

There have been a few studies done on the gas exchange during breath holding and numerous findings have been observed, which are pertinent to the writer's study.

One of the most important phases of the gas exchange in the alveoli during breath holding is the increase in the $PACO_2$ and the decrease of PAO_2.[20:223, 29:221] This of course is due to the lungs not being able to receive atmospheric air to supply it with oxygen, thus there is an increase in carbon dioxide.

In Astrand's[20] study of breath holding and exercise, he found that this increase in $PACO_2$ was very high during the first ten seconds of breath holding during exercise, but as it continued, it gradually leveled off. He states the following:

> This smaller increase is partly explained by the high carbon dioxide storing capacity of the blood and tissues during breath holding,...and the probable reduced carbon dioxide production when oxygen supply becomes insufficient. Furthermore, it should be emphasized that the concentration of carbon dioxide in the lungs will increase as oxygen is diffusing into the blood and the total volume of gas becomes diminished 20:223

Craig[28] et al concluded that the time the breath can be held depends upon the amount of work load which is used. It must be considered that Craig, used different concentrations of 100% oxygen.

Cummings[29] did his experiments on four males, letting them hold their breath and perform work on the treadmill. They held their breath and exercised until the breaking point was reached. The longest time was recorded at 29 seconds at 12 miles per hour on the treadmill. He discovered that this increase in $PACO_2$ was due to the ..."greater cardiac output during exercise, more blood from working muscles would profuse the alveoli..."[29:223] He also found that the men had a greater urge to breathe as the workload on the treadmill increased.[29:221]

Craig and Babcock[26] experimented with alveolar carbon dioxide of exercising subjects employing breath holding after breathing 100% oxygen, which means the increase was faster than when atmospheric air was inhaled because atmospheric air only has around 20% oxygen. This in itself would make breath holding time longer.

In a symposium presented by Mithoefer,[8] he stated that the breath could be held for varying periods of time depending upon five factors: lung volume, inspired gas concentrations, ambient pressure, metabolic rate and psychological elements.[8:195] He concluded that the decrease in lung volume which occurs during breath holding is due to the lungs not receiving air from the outside, which would indicate the air would only be shipped out from the lungs without reserve support coming in. As this lung shrinkage occurs the carbon dioxide is concentrated in the lungs and the partial pressure in the lungs rises. This will decrease the amount of carbon dioxide delivered to the lungs by the blood because of the pressure gradient between mixed venous blood and alveolar sacs being decreased. This will speed up the shrinkage of the lungs which will increase the carbon dioxide in the alveolar and arterial blood.[8:200-201] Mithoefer concludes the following:

> By this mechanism, anything that increases oxygen uptake, for example, exercise, will decrease breath holding time by increasing $PACO_2$ through the mechanism of volume shrinkage as well as by depleting oxygen supply and increasing metabolic carbon dioxide production.[8:201]

Mithoefer[51] also experimented with three subjects and a dog on breath holding, examining the alveolar air released at the breaking point at rest. In the dog, he went to an extreme; far beyond what a normal human being could withstand in breath holding. He found in the dog that the venous blood carried more carbon dioxide than the arterial blood and was more acidic at the onset of hyperventilation. As breath holding time increased the arterial blood gradually became more acidic and eventually reached a negative ratio exchange. This negative exchange produced a reverse exchange of the lungs and the arterial blood. That is, carbon dioxide began to diffuse from the lungs into the arterial blood because of no carbon dioxide output. He concluded that the three reasons for this rise in carbon dioxide in arterial blood are: (1) no carbon dioxide output, (2) lung shrinkage, (3) oxygenation of hemoglobin.[51:709]

In summary Mithoefer states:

> A self-perpetuating cycle is established during breath holding which depends upon opposing factors in the transport of carbon dioxide by arterial blood and venous blood. The arterial blood becomes subject to influences which tend to elevate its carbon dioxide tension rapidly, while opposing factors tend to limit the rise of carbon dioxide tension in venous blood. The effect is progressive depression of carbon dioxide output into the lungs with eventual reversal of carbon dioxide transport such that carbon dioxide moves from the lungs into the blood (51:710)

In a third study performed by Mithoefer, he examined the possibility of lung volume restriction being a ventilatory stimulus during breath holding. He concluded that if hypoxia is not present, the carbon dioxide can be tolerated to a much higher degree and that this toleration is directly related to the amount of gas that is in the lungs.[51:701] He states: "The findings are consistent with the existence of an independent ventilatory stimulus from volume restriction which interacts with the chemical stimulus from carbon dioxide"[51:702] He also concluded that when the breath is held at less than a maximal inspiration, the gas tension will change more rapidly than if the person inspired maximally. The partial pressure of carbon dioxide is higher at the breaking point with large volumes than it is with small volumes.[51:703] Mithoefer summarizes his experiment with this statement. "Lung volume restriction is a ventilatory stimulus during breath holding, which

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Cain[23] also supports the conclusion of Mithoefer that there are other factors beside the chemical stimulus of carbon dioxide that affects the breaking point of breath holding.[23:87] The stimulus could very well be due to ventilation.

In an additional study performed by Kloche and Rahn[40] with breath holding at rest, they supported the theory of decreased lung volume in a linear fashion. They felt that this decrease in lung volume was due to the oxygen uptake and that there was only a small concentration of carbon dioxide going either in or out of the lungs, due to the alveolar carbon dioxide being concentrated in the blood. They concluded after taking carbon dioxide samples at the beginning of breath holding and at the end, that their concentrations were almost the same.[40:692]

Chapin[24] agrees with Mithoefer on the observation that the breath can be held longer with larger volumes than with smaller volumes.[24:88] There is a higher breaking point of PCO_2 and PO_2 as well as a large ratio between carbon dioxide changes and oxygen changes when large volumes of air are inhaled. There is also a different gas composition at the breaking points when different volumes of air are inhaled. This of course is to be expected.

Dubois[34] concentrated his studies on the alveolar oxygen and carbon dioxide during breath holding. He found many of the same conclusions that other experimenters had found with additional explanations to one...."the rate of carbon dioxide output is proportional to the arteriovenous content difference and the cardiac output..."[34:2] At a point during breath holding this difference in arterial and venous blood is zero, which according to Dubois would affect the carbon dioxide output.

Lamphier and Rahn[42] experimented with breath holding using atmospheric air. They calculated the PCO_2 and the PO_2 of alveolar air at different points during breath holding. They concluded that because of lung shrinkage and the Haldane effect, the alveolar-arterial PCO_2 was way above the mixed blood during breath holding, but they added that the reason for such a concentration of carbon dioxide in alveolar air was possibly due to the PCO_2 of mixed venous blood, which of course comes from the tissues. To further understand this they suggest more investigations about the cardiac output and carbon dioxide tissue storage during breath holding.[42:481-482]

Ross et al.[59] experimented with the diffusing capacity of the pulmonary system during breath holding and exercise. They discovered that the diffusing capacity of the pulmonary system will increase during breath holding, but this increase is probably due to exercise; for with exercise alone, the diffusing capacity increased due to the need of oxygen by the tissues[59:797] and not due to an increase in ventilation.[57:796] This increase could have possibly been due to the increase in pulmonary capillary blood volume although it is still not actually understood.

In a study done by Michael et al.,[47] they experimented with underwater divers and their response to breath holding. They used this study to relate breath holding and exercise. They discovered, as has been mentioned before that breath holding is probably psychological as much as physiological. Individual differences as to their tolerance level was very important when trying to find a person's response to breath holding. Because of the differences in pulse rate between exercise with breath holding and at rest, Michael et al., concluded that there was possibly a constriction in the blood vessels during breath holding, which indicate a slowing down of cardiac output.[47:31]

In a second study done by Michael,[48] he again experimented with breath holding and underwater swimming. He was interested in the fitness relationship between underwater swimmers and trained athletes. Michael states:

> The conditioning program of athletes who exercise to the point of severe dyspnea, then rest, then exercise, may involve an adaptation to hypoxia. If this is true, and if hypoxia is a stimulus for circulatory conditioning, training for underwater swimming should result in better performance on exercise tolerance. 48:218

He found that the group's fitness levels were not significantly different and that the combination of exercise and breath holding would probably improve the condition of the athlete more than just exercise alone.[48:219]

In Pechinski's study, which was done at the University of Illinois, he discovered that breath holding with interval running had no effect on the endurance level of the subjects involved.[64:59] Pechinski used the breath holding variable at the end of his subject's interval running and not during the interval run.

In conclusion of the literature on breath holding and carbon dioxide and oxygen exchange, it should be remembered that breath holding will be a great stress as well as a great stimulus to the body; especially when exercise and breath holding are combined. The exchange of gases during breath holding, as indicated in the literature is the direct cause for the termination of the hold. Because of this, all of the subjects must be free of all respiratory aliments and other factors which might take away from their abilities to hold their breath.

Endurance

Endurance can be defined as the ability to continue work or exercise.[39:419, 16:237, 15:26, 6:322] In this study the writer was interested in the endurance level of the subjects more than any other aspect of the cardiovascular or cardiorespiratory systems. Endurance, has been considered as a measure of physical fitness; for endurance runs are usually included in physical fitness test. When endurance is discussed, the factor of will power, which is of most importance because of fatigue stress, should be considered. 32:29, 16:239 The ability to continue exercise a little longer or go a little further is will. Endurance can not be developed over a short period of time.[39:420] It cannot be improved in two or three practices, but it must be a continuous exertion of the body from six to eight weeks before any changes will take place.[2:5] This change will depend upon several factors: (1) type of exercise, (2) difficulty of exercise, and (3) frequency and duration of practice.[39:420] Large groups of muscles must be involved in endurance and used for a long period of time.[14:38] Doherty[32] recognizes three principles which must be considered in endurance: (1) Avoid doing too much too soon and thereby losing more than you gain, (2) The muscle group involved in each exercise should be large enough to affect the heart and breathing rates in a short time, (3) Recognize that the conditions under which these exercises are taken are essentially boring. 32:30 In considering these three principles each are of the utmost importance. In the first principle the exercise program for endurance must begin at a slow pace and gradually build up to a maximum. In the second principle, when all parts of the body are used, the heart and respiratory system will feel the effects faster than when only the arms or hands alone are used. In the third principle, if the factor of boredom is inserted then the will to continue the exercise will be a motivation for the participant.

Cureton[2] states the following:

> Endurance may be developed within the limits imposed by inherent constitutional type... The most important way to develop endurance is through hard work, repeatedly, or constantly performed to the limits of one's ability and time...2:5

An important factor must be remembered from this statement. To add excessive weight to these repetitions, that is weight far beyond the ability of the participant, will defeat the purpose of endurance; for in endurance the concentration is made on the work repeated and not heaviness. "Endurance exercises increase heart rate more than strength exercises..."[14:57] The cardiorespiratory and cardiovascular systems, which involve the heart are important in endurance; therefore extreme additional weights should be avoided.

Morehouse and Miller[16] comment on endurance by stating the following:

> Endurance for exhaustive work depends mainly on the ability of the body to supply and use oxygen and to endure and dispose of the rapidly mounting concentrations of lactic acid, and carbon dioxide and on the functional capacity of the heart, lungs, kidneys, and other organs that sustain activity. Training for endurance results in an increased capillarization of the muscle, thus providing more channels for the delivery of oxygen and food and the removal of waste.16:237

This physiological statement about endurance explains why endurance is an important factor in physical fitness.[39:419] The body will function to a much greater degree with less effort due to endurance.

> To summarize, an athlete with great endurance can carry on exhaustive work for a longer period and can establish a physiological equilibrium at higher levels of work. He can recover from work more quickly and is thereby enabled to start a second piece of hard work sooner than can a person with poor endurance.16:243

Training and Conditioning

To a coach, one of the most important factors which he considers about his team is the physical condition of his players. He naturally deals with this problem by putting these players through an extensive and well planned training program to have his participants be in the best physical condition possible. As the coach knows the better the condition his players, the longer they will participate and the longer they will be able to stay in a game without becoming physically fatigued. Brouha[9] states the following about training:

> Many physiological responses are altered by training. In general the improvement in each bodily system is of the order of 25 per cent or less, but when taken together all the effects may result in an improvement of total performance which may be as high as 100 per cent and occurs in both the magnitude and duration of the work, which can be done. 9:403

Klaf and Arnheim define training..."as a systematic process of repetitive progressive exercises of work, involving also the learning process and acclimatization."12:64

A training program is pertinent to athletes for many reasons: it helps prevent injury by building up the ligaments and tendons of the muscles to prevent sprains and strains; increases strength and endurance; and the athletes will recover quicker from injuries if they are in good condition. 5:40 Dayton[5] states:

> The physical conditioning results from the organs of the body being able to hold their efficiency at higher levels of activity. Skills are developed because the athlete learns to perform the act with a better economy of muscular effort.[5:40-41]

Training can provide many physiological changes in the athlete's body which makes it much easier for the athlete to play the game with ease. When the pulse rate of the athlete is taken before training and after training there appears to be a difference. Sometimes this rate is from 3 to 20 beats slower.[14:64, 16:260, 12:69, 25:429] Cogswell[25] et.al in their study of physical efficiency found that the systolic and diastolic pressure decreased gradually, which indicates a possible improvement of the vascular system when at rest.[25:429] The heart has been found to increase in size, be more powerful, pump more blood, and have a much stronger stroke volume due to training.[16:258, 15:30, 14:124, 12:60, 9:409]

Henry[36] indicates in his study of physical training that the one reliable way to test the improvement of the body, due to training, would be to test the heart rate before training and compare it to the heart rate after training. He felt there should be a significant difference in heart rate.

Cureton[30] also discusses the relationship of endurance and the heart. He states: "The development of the heart stroke parallels the development of endurance quite well, improving slowly over several years."[30:70]

Not only the heart muscles, but all other muscles of the body tend to become larger and much stronger due in part to the improved circulation of blood.[15:30, 14:298, 5:43, 12:65]

Schneider and Karpovich[17] states:

> Regular and heavy muscular work tends to thicken and toughen the sarcolemma of the muscle fiber and to increase the amount of connective tissue within the muscle. As a result of the latter change, the meat of heavily worked animals is tougher and coarser than that of those that have lived inactive lives.17:21 It is also important to bring out the fact that the muscle improvement due to training is not because of new fibers being made, but because the fibers which normally do not work are strengthened because of the extra work and thus the muscle as a whole increases.17:404

Training also improves the respiratory system of the body. The distribution and use of oxygen becomes very important in order to supply the muscles with additional oxygen. Training helps the athlete to consume more oxygen and also to withstand a much higher oxygen debt.[16:258] There is also an increase in carbon dioxide expired, but is usually not seen until after the fourth or fifth week of training.[14:114] If training is terminated after four or five weeks, these same improvements will tend to show up several months later.[45:114] The respiratory muscles become much stronger due to training, which helps the trainee move a larger portion of air in and out of the body. This is due to the respiratory movements becoming more abdominal than being performed by the rib cage.[13:247] The chest seems to be able to expand much wider, thus increasing the vital capacity and also the diffusing capacity of the alveolar membrane due to training.[17:140] Morehouse and Miller state:

> The increase stretching of the lung tissues results in a thickening of the alveolar septa and increase in elastic fibers, and perhaps the actual production of new alveoli. This excessive multiplication of alveolar tissue represents a true hyperplasia (formation of new elements, not simply enlargement of already existing elements), and is called "sport lung". Training also causes a marked hypertrophy of the diaphragm. The improved respiratory efficiency resulting from training is manifested by a greater absorption of O_2 per liter of ventilation.[16:262]

Another important system, which the process of training increases is the neuromuscular system. The trainee develops better coordination and his motions and movements tend to be more relaxed and easily performed. His energy expenditure for his performance tends to de-cease because the trainee finds that it does not take as much effort to perform his movements as it did at one time.[9:405]

The blood flow also finds improvement through training. The red corpuscles in the blood are increased and become more conditioned in carrying oxygen to the tissues. The trained individual has more corpuscles per cubic millimeter of blood than the untrained person and this helps during the oxygen debt.[13:135] Because of the reduction of oxygen needed by the muscles due to training, the blood is better able to carry blood to other organs of the body, which might need it.[9:409-410]

We have been speaking of training as a hard work-out, but physiological improvements will occur with just a moderate amount of exercise each day. This was proven by Schneider[60] in his study of moderate exercise. He only worked with two subjects, but their improvement was significantly better. He continues to say that moderate exercise not only improves the efficiency of the body, but the nutritive condition as well. He observed that the moderate amount of exercise which he gave his subjects even resulted "in a noticeable increase in the feeling of well being and mental alertness"[60:1] Schneider concludes: "The data gathered in this investigation of the effects of training show that moderate physical exercise, about an hour daily, increases the load-carrying ability within one week, but from five to seven weeks are required to bring out full effects."[60:7]

In conclusion it can be said that all types of physiological tests which can be given, will indicate improvements in physiological function due to training and also will show negative changes if training is ceased.[3:509]

The person who is not an athlete will just in general feel better and be less susceptible to some infection, due to some type of training or conditioning program.[14:280] "Nothing but vigorous exercise will bring about these changes. These are not the gifts of any age, sex, or race;- they are the hard-earned rewards of repeated exhaustive effort."[15:30]

Physiological Effects of Training on the Heart

Of all the parts of the body which are changed by physical training, the heart is probably one of the most affected. The heart, because it is a muscle as well as an organ will grow and develop strength through training. As Karpovich states, "It seems, ... to be clear that the heart muscle, like any other muscle, reacts by hypertrophy to the greater demand physical activity imposes upon the circulatory system".[11:183]

As noted by the above statement, one of the effects of training on the heart is an enlargement and an addition in weight. Heaviness, as reported by Jokl, is probably due to the increase in muscle of the auricles and ventricles as well as an enlargement of the chambers themselves.[10:28] This additional weight which the heart might gain is accomplished if severe training is performed such as the training used in vigorous competitive athletic events. Morehouse and Miller state:

> Endurance sports enlarge the right side of the heart, whereas short, intense execution produces a greater change in the left side of the heart. Hypertrophy

> of the right side of the heart is attributed to elevated pulmonary circulatory resistance and increased venous return to the right heart during prolonged and repeated exercise. Hypertrophy of the left heart following repeated short bouts of violent exertion may be due to the increased work of the rapidly contracting heart against the elevated blood pressure in the systematic circulation. 10:260

This increase in size, as told by DeVries has only been seen directly in animals, but investigators seem to apply these facts to humans. On the other hand, Hyman (cited from Karpovich)[11:184] has experimented with the size of the heart due to training. He took x-Rays of his patients' heart, outlined them on paper, cut the outline out, and taped it on the patient's chest to be photographed. This provided an opportunity to study the size of the heart visually. He has used men who were athletes in their younger days and men who were athletes at the time of the experiment.

In order to clarify discussion on the heart size, it must be remembered that this growth is physiologically normal. Patients who have a diseased heart might have an increase in heart size, but this is pathological.

The heart rate in most instances is slower during exercise and recovery. DeVries[6:76] agrees with this theory and adds that the trained person can do more work than the non trained person as well as recover faster from the work load. Jokl[10:49] reports that the best well known athletes have slower heart rates than the lesser known ones. The decrease in heart rate does not occur over a short period of time, but as noted in the experiment by Knehr and others,[41] their subjects took six months before a decrease of 5 beats was observed in the heart rate. These subjects were training by middle distance running.[41]

To make up for the decelaration of the heart rate, the heart must be more powerful with every beat. This would mean an increase in stroke volume, which would indicate ...." an adequate cardiac output.... at a lower pulse frequency".[21:183] This according to Morehouse and Miller[16:290] would compensate for the slower pulse rate during exercise, recovery, and rest. The increase in stroke volume is due to "....the greater contractility and consequent greater systolic emptying of the ventricle in the heart of the trained athlete". (Cited in DeVries)[6:76] In stroke volume, as does most effects of training, a long time is needed before the effects of training are noted, and endurance training is the key to the increase.[6:76]

Heart Rate as a Measure of Physiological Strain.

In studies which were mentioned previously in the literature, oxygen consumption was used as a measure of physiological strain and energy expenditure. The question now arises- "Can the heart be a valid measure of strain and energy cost"? It seems to be the general consensus of researchers that strain has a linear relationship with oxygen consumption.

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In a study done by Maxfield and Brouha,[46] the possibility of heart rate being a measure of physiological strain was investigated. They found that there was a linear relationship between work done and the rate of the work during exercise and recovery. This would give a clear picture of the amount of physical strain on the heart.

Davies and Harris suggest from their experiment that the simple count of the pulse rate would be sufficient enough to determine work capacity.[31:8] They also caution an experimenter about the emotional upset of the subject when the pulse rate is taken, which would indicate the need for several pilot studies before a realistic count is taken during any of the phases of physical activity. A linear relationship between the pulse rate and energy expenditure has been experimented with by Malhotra,et al.[44] They comment that the relationship between the circulatory system and the respiratory system is definitely present because of the circulatory system carrying the oxygen to the working muscles. An indication of a relationship would be possible since the lungs provide the circulatory system with the oxygen.[44:996]

These experiments were performed on men, but the results can be applied to women also. In a study done by Michael[47] on college women, he found a direct relationship between oxygen volume and heart rate during exercise. One of the reasons for the importance of this study is because it was one of the few studies which was performed with women during work. Because of the difference in certain physiological parameters between men and women, more studies need to be conducted using women as subjects.

Caloric expenditure has been used to determine the amount of calories used during a certain work load. LeBlanc,[43] in his study of heart rate and work, wanted to find an easier method of determining caloric expenditure instead of using the tedious method of gas analysis. He found that the pulse count was a good indicator of caloric expenditure. "Therefore, if the VO_2 is plotted against the heart rate... the VO_2 at any heart rate level can be predicted".[42:277] This could eliminate gas analysis and become a laboratory short cut. He makes one final conclusion; this linear relationship can only occur up to around 185 beats per min. because of the distortion which occurs at this point with the oxygen consumption. This would indicate that the two systems would react differently to physiological strain if distortion was noticed at the level of 170-185 beats. When the heart reaches this level, the respiratory system seems to be working without oxygen, which would cause the amount of oxygen consumption to level off due to anaerobic conditions.[21:1098]

Reeves et al[57] submit a conclusion that the oxygen consumption has a relationship with cardiac output during rest as well as with body surface area. This relationship is due to the difference in arteriovenous oxygen levels. 57:276 The Fick method was used as the measuring method as it was in several of the studies mentioned above.

CHAPTER IV

PROCEDURE

The procedure for this study is discussed according to the selection of subjects, pre and post tests given to each subject, measurement techniques, and an explanation of the training programs themselves.

Selection of Subjects.

Thirteen women graduate students at the University of North Carolina at Greensboro in the Physical Education Department were selected as subjects for this experiment. These girls ranged from the age of 22 to 26. None of the subjects were engaged in any regular activity program and all exhibited a willingness to participate in the study. Because of the variable of holding the breath being involved in the experiment, the subjects had to be ones who would complete the experiment. This meant that the girls in the breath holding group could possibly experience some discomfort which might discourage them to the point of withdrawing from the experiment. After the thirteen graduate students were selected, they were told to continue their normal daily activities of eating, sleeping, smoking, and drinking.

Instruments used in the pre and post tests.

Two instruments were used in the pre and post testing periods. They were the Physiograph used in this study to measure heart rate during exercise and the Scholander gas analyzer, designed to measure the oxygen consumed from atmospheric air.

Physiograph.

The physiograph is an instrument used to measure various physiological parameters. The Physiograph Four, which was used in this experiment, is built to measure three physiological variables simultaneously, and consists of several parts which shall be described.

1. Main Frame- This consists of the pockets for the amplifier and other controls. The pen recorder along with the graph paper, ink supply, time recorder, and paper feeder are included in this main frame.[7:2-2]

2. Amplifier- A device which receives the signal from the transmitter, and amplifies it to such a degree that the pen needle moves in order that the recording can be made on the paper.[7:2-1]

3. Transducer- Converts the physiological impulses into electrical signals which are a necessity for recording. 7:2-1

4. Pen Recorder- Receives the signals from the amplifier and reacts accordingly to the physiological activity.[7:2-2]

5. Transmitter- The transmitter is a small device two inches high and one inch wide. The purpose of this piece of equipment is to transmit the physiological activity- in this case the heart beat into the pre-amplifier for recording.

Because of this device, there are no direct cords connecting the subject and the physiograph's main body frame. The transmitter was taped to the outside clothes of the subjects in this experiment.

6. FM Receiver- This is a regular FM radio, which is designed specifically for the physiograph. It picks up the frequency from the transmitter and transmits the signal to the pre-amplifier.

7. Pre-Amplifier- A device used to give more amplitude to the signal because the amplifier does not have enough energy to record the signal; therefore an additional device is needed to make the signal stronger.

8. Electrodes- Small attachments which go directly on to the body and attach from a cord to the transmitter. This is the place that the initial signal begins to pick up the heart beat.

Scholander Gas Analyzer.

The Scholander Gas Analyzer was the apparatus used to determine the oxygen consumption of the subject.[18] This analyzer operates on the principle of gas absorption. An oxygen absorbant and a carbon dioxide absorbant are released in a reaction chamber on the Scholander where absorption of the two gases takes place. The volumes of the gases are read according to micrometer divisions. The gas is inserted into the gas analyzer by a syringe, which is filled with expired air obtained from the subjects.

Pre and Post Tests.

Appointments were made with each graduate student to come to the research lab for the pre and post tests. Both of these tests were administered identically in order to alleviate any other variables which might exist in the experiment. Since the subjects came at different hours of the day, the times were the same for both pre and post tests. (Example- During the pre test one subject came at 2:00 o'clock for the pre test and at 2:00 o'clock for the post test.)

The testing period started February 14, 1968. Upon entering the lab each subject was dressed in shorts, a shirt, and sneakers. She was weighed and her height was taken. The electrodes were placed on the subject, one at the top of the sternum and the other at the bottom of the last two real ribs. (Several weeks before the testing began, different placements of the electrodes were tested by the experimenter. It was found that the top of the sternum and the last two real ribs were the most effective placement.) Each electrode was taped securely to the individual to keep the cords from moving against the skin and causing artifacts in the readings of the physiograph. The subject sat in a chair in front of an 18 inch bench, which was used for stool stepping. (Stool stepping was selected because it was a heavy work load for the subjects to perform and could be standardized. In addition the physiograph readings were much easier to read because the subject did not move her body enough to jar the transmitter or tear the electrodes off the skin.) A cushioned nose clip was placed on their nose to prevent them from breathing through the nose. Each subject was told the following:

> You will rest for five minutes with the Collins Triple J high velocity two way breathing valve in your mouth. On the left of this valve, there is an opening which the air you breathe will enter. Do not place your hands over this opening at any time during the test. You may hold the valve with one hand or two, depending upon which is comfrotable for you. At the end of the five minutes of rest, the time buzzer will sound and you will immediately take the valve out of your mouth. On the "Go" signal you will stand up, place the valve back in your mouth and stool step for three minutes. You may start with either foot to begin the exercise. Make sure that as you step up on the bench, you completely straighten both legs and come to a standing position before you step down off the bench. The metronome will be set at 100 revolutions a minute. The steps up and down on the bench should correspond with the rhythm of the metronome. At the end of the three minutes, the buzzer will not sound, but I will give you the "STOP" signal and you will immediately sit down. Please keep the valve in your mouth during the recovery period which will last for ten minutes. At the end of this ten minutes, the buzzer will sound and you will take the valve out of your mouth.

After each subject had finished the testing they were free to leave.

Five gas samples were taken for each subject during the test. One taken during rest, one during exercise, and three during recovery. The sample during rest was taken at the three and one half minute point of the five minute rest. The sample for exercise was taken one and a half minutes into exercise. The first sample for recovery was taken at the first minute of recovery, at the fifth minute, and at the ninth minute.

The amount of air which was exhaled by the subject was measured by the gas meter. The meter readings were read in liters. This reading was necessary in order to determine the caloric cost. The meter also provided the expired air temperature readings which were used to convert the air volumes to standard conditions in relation to temperature and barometric pressure. The barometric reading was taken from an army signal corps type barometer, and corrected for room temperature.

Selection of Experimental and Control Groups

Caloric cost was calculated for each subject of the pre test exercise and used to equate the groups according to this caloric expenditure for the exercise. The subjects were randomly selected and after applying the Fisher "t" for small uncorrelated groups, no difference was found between the groups at the five per cent level of confidence. There were 7 breath holders (experimental) and 6 non-breath holders (control) in the study. After two weeks into the program, one subject in the experimental group dropped out due to headaches, which she received from the training program. This divided the group equally at six and six. An additional "t" test was used to see if the groups were still equated and no statistical difference was found.

Training Programs.

The training program was set up for three times a week lasting for six weeks. On February 20th, the program started. There were two exercising periods a day. One at 10:00 in the morning and the other at 5:00 in the afternoon. The programs were conducted on Tuesday, Wednesday, and Thursday. Four in the experimental group and three in the control group exercised at 10:00 in the morning. Three in the experimental group and two in the control group exercised at 5:00 in the afternoon. Both periods were conducted identically with the same exercises and at the same rate of speed. The metronome was used for each exercise set at 100 revolutions a minute, which was the same rate as the pre and post tests speed. Each person in the experimental group wore nose clips, which were the same type used by swimmers. This was to prevent them from breathing through the nose while the breath was held.

Eight calisthenics were selected on the basis of the all out effort it would take for the subjects to perform. These were the jumping jacks, toe touches, sprinter's start, running in place, explosive jump, hopping in place, sit-ups, and push-ups. Each exercise was performed in the same order each time the training program was conducted. Each exercise was performed for a certain length of time and at a specific speed. The first week the exercise was performed for 13 seconds. Two seconds were added to this time at the beginning of each week up until the beginning of the fourth week and it became necessary to stop the increase because of the severe pain each breath holder was enduring and because at this time the subject with the headaches dropped out. She felt that the headaches were brought on because of the length of time she was holding her breath. The last three weeks of the program the exercises were performed at a constant time of 17 seconds. Each exercise was performed to the count of the metronome and at the end of each a ten second rest period was observed. To start each exercise, the experimenter issued the following directions. Breath holders exhale- inhale- hold- and begin. At the command "BEGIN" everyone started the calisthenics. The calisthenics were ended by the buzzer of the clock after the prescribed amount of seconds.

Gas Collection and Metering Technique.

A Collins Triple J high velocity two way breathing valve was suspended in the air by cords with rubber corregated tubing of one and one quarter inch inside diameter attached to the outlet valve. This rubber tubing led to the inlet side of a sample chamber which in turn was attached in like manner to a Thomas Dry Test Gas Meter. The sample chamber was a copy of a model designed by Pleasants.[65] It was constructed of clear plexiglass in the shape of a cylinder, approximately eight inches in length and six inches in diameter, with two vaccine stoppered holes in the top for procurring expired air samples.

Twenty cubic centimeter syringes with no. 22 needles were used to draw the samples from the chamber. After inserting the needle of the syringes into the vaccine cap, the syringe was slowly flushed three times before taking the sample.

Gas volumes were recorded periodically from the gas meter. This method of direct sampling and direct metering was proven to be a valid technique by Pleasants and Campney[56] when compared with the conventional Douglas bag technique.

Statistical Analysis.

The Fisher "t"[19] for small uncorrelated groups was used to compare the two groups energy cost, total resting heart rate, total exercise heart rate, and total recovery heart rate.

CHAPTER V

STATISTICAL ANALYSIS OF DATA

This chapter is concerned with the analysis of data, which was arrived at by the use of statistics. The conventional Fisher "t" for small uncorrelated groups was used to determine the significance of difference between the control and experimental groups in relation to caloric expenditure, total resting heart rate, total exercise heart rate, and total recovery heart rate, due to the calisthenic training program. All raw data for these four physiological measures appear in the Appendix.

The 5% level of confidence was used to determine the error outcome for rejecting the null hypotheses. Four hypotheses were set up prior to the experiment and put in the null. They are as follows:

1. There is no difference between experimental and control groups due to the variable of breath holding with calisthenics.

2. There is no difference between experimental and control groups resting heart rate due to the variable of breath holding with calisthenics.

3. There is no difference between experimental and control groups in exercise heart rate due to the variable of breath holding with calisthenics.

4. There is no difference between experimental and control groups in recovery heart rate due to the variable of breath holding with calisthenics.

The caloric cost was determined by oxygen consumption and read in liters, while the total heart beats for each phase was used to compare the groups. The differences between the pre and post test scores for caloric cost and heart rate for rest, exercise, and recovery were calculated before applying the Fisher "t" for small uncorrelated groups. These group differences were compared between the experimental (breath holders) and control (non-breath holders) groups.

After the pre test, the groups were equated and there was found to be no difference in the two groups according to caloric cost. The calculations for this comparison are presented below.

TABLE I

EQUATION OF GROUPS (With 13 Subjects)

Before

	Mean	M.D.	t*
Ex.	25.25	.08	.029
Control	25.33		

*Required 2.20 for significant difference

TABLE II

EQUATION OF GROUPS (With 12 Subjects)

After

	Mean	M.D.	t*
Ex.	25.61	.29	.117
Control	25.33		

*Required 2.23 fpr significant difference

Caloric Cost

The caloric cost for the pre test and the caloric cost for the post test for both experimental and control groups were determined by substracting the results from the pre test from the results of the post test. The two groups were compared again by the use of the Fisher"t" for small uncorrelated groups. These comparison are presented below in Table III.

TABLE III

COMPARISON OF CONTROL AND EXPERIMENTAL GROUPS CALORIC COST

	Mean	M.D.	t
Ex.	-.543	-.158	-.0261
Control	-.385		

Required 2.23 for significance

The value of "t" was not significant beyond the 5% level of confidence; therefore the first null hypothesis was accepted to be true.

Heart Rate at Rest

The total heart beats for five minutes of rest of each subject was determined for both pre and post tests. The difference of these two figures was found by the substraction of each subject's pre test and post test scores. The results of these comparisons are presented below in Table IV.

TABLE IV

COMPARISON OF CONTROL AND EXPERIMENTAL GROUPS
RESTING HEART RATE

	Mean	M.D.	t
Ex.	16.67	11.67	.552
Control	5		

Required 2.23 for significance

The value of "t" was not significant beyond the 5% level of confidence; therefore the second null hypothesis was accepted.

Heart Rate During Exercise

The total heart beats for three minutes of exercise for each subject was determined for both the pre and post tests. The total beats for the pre test and the total beats for the post test were determined for each subject and the difference of these two scores was taken to use in the comparison of the two groups. The comparisons are presented below in Table V.

TABLE V

COMPARISONS OF CONTROL AND EXPERIMENTAL GROUPS
EXERCISE HEART RATE

	Mean	M.D.	t
Ex.	-16.5	29.17	-1.42
Control	12.67		

Required 2.23 for significance

The "t" was found not to be significant at the 5% level of confidence and again the third null hypothesis was accepted.

Heart Rate and Recovery

The total heart beats for 10 minutes of recovery was determined for each subject for both the pre and post test of the experimental and control groups. The difference between these scores was taken and used for comparison. The results are shown below in Table VI.

TABLE VI

COMPARISON OF CONTROL AND EXPERIMENTAL GROUPS
RECOVERY HEART RATE

	Mean	M.D.	t
Ex.	-63.67	-65.67	.549
Control	2		

Required a 2.23 for significance

The "t" was not found to be significant at the 5% level of confidence. This made it possible to accept the fourth and final null hypothesis.

INTERPRETATION OF STATISTICAL DATA

As noted by the statistical formula, all of the null hypotheses were accepted at the 5% level of confidence, but interestingly enough there were several items which should be elaborated upon. Both the experimental and control groups tended to decrease in their energy cost for the three minute exercise on the post test, with an average mean decrease of .543 with the experimental group and .385 with the control group. Although these two groups were not significantly different in their means at the end of the training period, it is unusual to note that everyone in the control group except for two people increased in their energy cost and everyone in the experimental group except two subjects decreased in their energy cost. In the control group Subject 2 decreased to an extreme, as compared to the rest of the group, which could possibly be the reason for the control group's mean decreasing instead of increasing. This subject in the control group seem to have the only extreme score in both experimental and control groups.

In the totals for the resting heart rate, everyone in the control group except two, and everyone in the experimental group except for two increased in their count for total heart beats during rest. The range in the experimental group was from -30 to +75 with a mean increase for the group of 16.67. The range for the control group was from -40 to +45 with a mean increase of 5. On the average both groups resting heart rate increased between the pre and post testing. Hopefully, due to the training, the resting heart rate would have decreased, but again there was a subject in each group who deviated from the entire group. Subject 4 in the control group decreased a total of 40 beats for 5 minutes of rest and Subject 5 increased a total of 45 beats. In the experimental group Subject 11 increased her heart rate 75 beats. Both Subject 5 in the control group and Subject 11 in the experimental group, from my observations of the post test, tended to anticipate the exercise (accelerated heart rate), which could increase the rate of the heart because of the emotional factor. No outstanding observation was made on Subject 4 in the control group and therefore no justification can be given for her extreme decrease in the total resting heart rate. Possibly it could have been due to the training program itself.

Again there was not a statistically significant difference in the pre and post tests for the experimental and control groups.

During exercise, there were interesting results which need discussion. In the experimental group, there was a decrease in the total heart beats of 99. With the control group, there was an increase of 76. It would seem that this would make a significant difference, but statistically there was no difference. The average decrease for the experimental group was 16.5 beats, while the average increase for the control group was 12.67 beats. Everyone in the experimental group's total exercise heart beat decreased except for Subject 11 and every subject in the control group except Subject 4 increased. Subject 11 and 4 have had both of the deviations for exercise and rest. There appears to be no explanation for this, but an additional observation can be inserted in this discussion which deals with both of these subjects scores. Subject 11 had one of the highest caloric costs for both groups, while Subject 4 had one of the lowest. Subject 11 was a medium size girl and tended to find the pre and post test difficult, while Subject 4 was a small girl and tended to find the pre and post tests relatively easy. These statements can be easily made after observation of both subjects.

In recovery, the average decrease for the experimental group was 63.67 beats and the average increase for the control group was 2. No statistical difference was found between these two groups in total recovery heart beats for ten minutes.

The readings of the raw scores for all four of the physiological measures, caloric cost, resting heart rate, exercise heart rate, and recovery heart rate in some instances tended to be significant, but statistically there was no difference among any of the four. One reason for this could be due to the number of subjects used in the study. With only a total of twelve subjects, the chances of the differences being significant were limited because enough of the total population was not represented. The variable of breath holding might not have any effect upon the caloric cost, resting heart rate, exercise heart rate, or recovery heart rate, but the possiblity of more subjects could give a clearer picture of the effects of breath holding upon endurance and heart rate.

The ability of the breath holding subjects to endure the discomfort involved in breath holding evidently had no bearing upon the results, although specified times were used during each calisthenic for the breath to be held and every subject always completed the breath holding period. Some subjects experienced discomfort, especially during the fourth week when the peak of the time was reached. If the breaking point for each subject had been used it may have affected the results of this study. At several points during the training program, headaches and dizziness in several subjects were noticed, but no side effects occurred after the training program was over.

It is also possible that the calisthenic program was not vigorous enough to act as a training stimulus for the subjects used in this study. Finally, it was evident that the subjects themselves did not enjoy the training; for several negative attitudes were observed in the breath holding group.

The variable of breath holding with calisthenics as a stimulus used in training programs should be investigated carefully before allowing it to enter into a full time program of training. Athletes who are training for a particular sport might find this type program helpful in building endurance, but the results of this study indicate a negative possibility.

CHAPTER VI

SUMMARY AND CONCLUSIONS

The purpose of this investigation was to determine the effects of breath holding with calisthenics upon energy cost, resting heart rate, exercise heart rate, and recovery heart rate.

Twelve physical education graduate students volunteered as subjects for the experiment, which consisted of a six weeks training program using breath holding with calisthenics. The subjects were first given a pre test consisting of a five minute rest period, three minutes of stool stepping and ten minutes recovery. The caloric cost for the exercise, the resting heart rate, the exercise heart rate and the recovery heart rate were calculated for each subject. The caloric cost was used as a basis for the equation of the two groups. There were six subjects in the breath holding group and six subjects in the non-breath holding group. Four breath holders and four non-breath holders exercised three times a week at ten o'clock in the morning for six weeks, while two breath holders and two non-breath holders exercised three times a week at five o'clock in the afternoon. At the end of the six week period, each subject was retested using the same test as was used in the pre test.

Findings

Four hypotheses were established at the beginning of the investigation. The Fisher "t" for small uncorrelated groups was used to find significant differences between the control and experimental groups. There was no significant difference between the experimental and control groups according to energy cost, total resting heart rate, total exercise heart rate, and total recovery heart rate, due to breath holding, at the five percent level of confidence.

According to the statistical analysis, the variable of breath holding with calisthenics had no effect upon the physiological parameters which were measured.

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APPENDIX

RAW DATA FOR ENERGY COST OF THREE MINUTES OF EXERCISE
FOR PRE AND POST TEST

Subjects	Pre Test	Post Test	Difference
1	23.58	25.25	+1.67
2	25.63	19.49	-6.14
3	22.42	21.73	- .69
4	22.51	22.92	+ .41
5	23.91	23.64	+ .27
6	33.31	35.48	+2.17
7	25.85	24.57	-1.28
8	24.28	23.62	- .66
9	18.31	22.35	+4.04
10	33.22	27.80	-5.42
11	30.94	28.07	-2.87
12	21.10	24.03	+2.93

RAW DATA FOR TOTAL REST HEART BEATS FOR PRE AND POST TESTS

Subjects	Pre Test	Post Test	Difference
1	390	395	+ 5
2	385	415	+30
3	330	350	+20
4	455	415	-40
5	250	295	+45
6	405	375	-30
7	395	425	+30
8	380	395	+15
9	475	490	+15
10	500	470	-30
11	320	395	+75
12	375	370	- 5

RAW DATA FOR TOTAL EXERCISE HEART BEATS FOR PRE AND POST TESTS

Subjects	Pre Test	Post Test	Difference
1	439	452	+13
2	478	502	+24
3	455	465	+10
4	479	446	-33
5	401	422	+21
6	379	420	+41
7	496	485	-11
8	454	399	-55
9	517	486	-31
10	501	491	-10
11	435	492	+57
12	426	377	-49

RAW DATA FOR TOTAL RECOVERY HEART BEATS
FOR PRE AND POST TESTS

Subjects	Pre Test	Post Test	Difference
1	975	1009	+34
2	1037	1026	-11
3	855	893	+38
4	1210	1141	-69
5	789	859	+70
6	1052	1002	-50
7	1093	1112	+19
8	1031	1009	-22
9	1219	1099	-120
10	1257	1037	-220
11	1023	1096	+73
12	918	808	-110

RAW DATA FOR SUBJECTS DURING PRE TEST FOR OXYGEN CONSUMPTION AND ENERGY COST (REST)

Subjects	CO_2(Ave)	O_2(Ave)	R.Q.	TO_2	Cal. of heat/ liter of O_2	Cal./13 mins. of Ex. and recovery
1	3.35	17.04	.82	4.02	4.83	18.35
2	2.52	17.64	.71	3.50	4.61	12.72
3	2.52	17.33	.64	3.89	4.60	14.21
4	2.57	17.11	.61	4.20	4.60	13.16
5	2.14	17.66	.60	3.61	4.60	18.17
6	2.63	17.62	.75	3.49	4.74	15.12
7	2.60	17.42	.69	3.75	4.60	13.01
8	3.32	17.07	.82	4.00	4.83	12.70
9	2.44	16.60	.51	4.79	4.60	17.94
10	2.33	17.72	.67	3.43	4.60	16.51
11	2.36	18.19	.79	2.81	4.79	12.84
12	2.23	18.53	.80	2.49	4.80	14.98
13	2.84	17.65	.82	3.40	4.83	14.44

RAW DATA FOR SUBJECTS DURING PRE TEST FOR OXYGEN CONSUMPTION AND ENERGY COST(Ex. and Recovery)

Subjects	CO_2(Ave)	O_2(Ave)	R.Q.	TO_2	Cal. of heat/ liter of O_2	Cal./13 mins. of Ex. and Recovery
1	3.16	17.57	.89	3.42	4.91	41.93
2	2.95	17.62	.85	3.39	4.86	38.35
3	3.20	17.45	.89	3.55	4.91	36.63
4	3.08	17.57	.87	3.42	4.88	35.67
5	2.77	17.89	.88	3.11	4.89	42.10
6	3.27	17.87	1.08	3.00	5.05	48.43
7	3.55	17.45	.94	3.52	4.95	38.86
8	3.65	17.25	.98	3.70	4.99	36.98
9	3.11	17.98	1.05	2.91	5.05	36.25
10	2.89	17.75	.87	3.45	4.88	49.73
11	3.18	18.04	1.12	2.80	5.05	43.78
12	3.07	17.84	.98	3.10	4.99	36.08
13	3.38	17.94	1.15	2.90	5.05	37.52

RAW DATA FOR SUBJECTS DURING PRE TEST FOR
BAROMETRIC PRESSURE AND TEMPERATURE READINGS

Subjects	Barometric Pressure	Corrected Barometric Pressure	Temp. (Room)	Temp.(Ave.) (Air)(Rest)	Temp. (Air) Ex. and Rec.
1	744.9	741.5	23°	22°	22.4°
2	748.5	747.1	23°	21°	22.6°
3	737.6	734	25°	25.5°	25.7°
4	741.3	739.4	25°	25°	25.5°
5	745.2	741.8	24°	24.5°	25.3°
6	745.9	742.3	25°	25.5°	26.6°
7	742.2	738.8	25°	25.5°	26
8	743.8	740.2	25°	26°	26.3°
9	740.4	739.5	25°	26°	26.6°
10	740.10	736.7	23°	22°	22.6°
11	745.3	741.9	23°	24.5°	24.3°
12	745.2	741.8	23°	23°	24°

RAW DATA FOR SUBJECTS DURING POST TEST FOR OXYGEN CONSUMPTION AND ENERGY COST(REST)

Subjects	CO_2(Ave)	O_2(Ave)	R.Q.	TO_2	Cal. of heat/ liter of O_2	Cal./13 mins. of Ex. and Recovery
1	2.43	17.82	.74	3.22	4.73	20.15
2	2.43	18.15	.84	2.81	4.85	13.73
3	2.63	17.55	.73	3.57	4.67	14.43
4	2.37	18.22	.83	2.71	4.84	13.46
5	2.63	18.24	.95	2.70	4.96	20.24
6	2.11	18.52	.85	2.45	4.86	12.64
7	2.86	17.51	.79	3.51	4.79	16.81
8	3.02	17.16	.76	3.95	4.75	13.59
9	2.37	18.16	.81	2.85	4.81	15.87
10	2.30	18.49	.93	2.45	4.94	14.92
11	2.50	18.09	.85	2.90	4.83	13.04
12	2.24	18.21	.76	2.85	4.75	15.44

RAW DATA FOR SUBJECTS DURING TESTS FOR OXYGEN CONSUMPTION AND ENERGY COST(Ex. and Recovery)

Subjects	CO_2(Ave)	O_2(Ave)	R.Q.	TO_2	Cal. of heat/ liter of O_2	Cal./13 mins. of Ex. and Recovery
1	3.62	17.30	.99	3.61	5.05	45.40
2	2.83	18.19	1.04	2.70	5.05	33.22
3	3.05	17.71	.92	3.25	4.94	36.16
4	3.06	17.82	.97	3.12	4.97	36.38
5	3.17	18.21	1.21	2.58	5.05	43.88
6	3.11	17.93	1.03	2.99	5.05	48.13
7	3.26	17.71	1.0	3.20	5.05	40.75
8	3.66	17.62	1.13	3.22	5.05	37.21
9	2.92	17.97	.98	2.95	4.97	38.22
10	3.07	18.20	1.15	2.62	5.05	42.72
11	2.97	18.27	1.04	2.65	5.05	41.11
12	3.21	17.64	.94	3.32	4.95	39.89
13						

RAW DATA FOR SUBJECTS DURING POST TEST FOR
BAROMETRIC PRESSURE AND TEMPERATURE

Subjects	Barometric Pressure	Corrected Barometric Pressure	Temp. (Room)	Temp. (Ave) (Air) (Rest)	Temp. (Air) Ex. and Rec.
1	746.6	742.9	26°	23°	24.3°
2	751.7	747.8	27°	25°	25.3°
3	749.5	745.9	25°	26°	25.5°
4	746.9	743.3	27°	25°	25°
5	743	739.1	27°	25°	25.29°
6	747.8	744.1	26°	26°	25.6°
7	745.8	741.9	27°	25°	25°
8	746.2	742.3	27°	25°	25.2°
9	747	743.3	26°	26°	25.7°
10	747.1	743.2	27°	25.5°	25.8°
11	749.8	745.9	27°	25.5°	25.5°
12	748.5	764.8	26°	23°	23.3°

SHEET USED FOR RECORDING DATA DURING PRE AND POST TEST

NAME____

AGE___________. HEIGHT______________. WEIGHT______________

BAROMETRIC PRESSURE______________. TEMP.______________.

TEMP. CORRECTION FACTOR___________. LATITUDE CORRECTION

FACTOR______________. CORRECTED BAROMETRIC PRESSURE_________.

M_1_______. T_1______. T_2______. T_A______. STPD CORRECTION

FACTOR______________.

V_1____________.

M_2______. T_3_______. T_4_______. T_5______. T_6_______.

T_7______. T_8_______. T_9_______. T_A______. STPD CORRECTION

FACTOR______________.

V_2_______________.

SAMPLE 1(Rest)

A_1______. A_2_______. A_3_______. CO_2/rest_______.

O_2/rest_______. R.O./rest_______. $TO_{2\,rest}$__________.

Cal. of heat/liter O_2=__________. $\frac{TO_2 \times V_1}{5}$ x 13 x Cal. of

heat/liter O_2= _________.

Calories produced during 13 mins. of rest.

	S_2	S_3	S_4	S_5
A_1	_____	_____	_____	_____
A_2	_____	_____	_____	_____
A_3	_____	_____	_____	_____
CO_2	_____	_____	_____	_____
O_2	_____	_____	_____	_____

CO_2 AVG.________. O_2__________. R.O.__________. TO_2________.

Cal. of heat/liter O_2__________. $(TO_2 \times V_2) \times$ (Cal. of heat/ liter O_2) =__________.

Calories during exercise and recovery - Calories during rest = ______________.

TECHNIQUE USED DURING THE ADMINISTRATION

OF THE PRE AND POST TESTS

SUBJECTS PARTICIPATING IN THE

TRAINING PROGRAM

TECHNIQUE USED DURING THE ADMINISTRATION

OF THE PRE AND POST TESTS

SUBJECTS PARTICIPATING IN THE

TRAINING PROGRAM

ILLUSTRATION OF THE GAS ANALYSIS TECHNIQUE

ILLUSTRATION OF THE GAS ANALYSIS TECHNIQUE